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FARM ANIMAL WASTE DISPOSAL

THE ONTARIO WATER RESOURCES COMMISSION

FARM ANIMAL WASTE DISPOSAL

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ABSTRACT

The Division of Research, Ontario Water Resources Commission has established a research program to investigate farm animal waste disposal methods. As an initial phase, this paper, dealing with the theories and implications involved with the processing, treatment and disposal of farm animal wastes, has been prepared.

Farm animal wastes have been contributing polluting materials to our waterways for many years. The changing nature of farming in the very recent years, however, has increased considerably the pollution potential of farm animal wastes. Since this change is still in process, an intensive study into improving the methods and facilities for the disposal of farm animal wastes is well justified, as the methods of disposal available to the farmer may well control the location and magnitude of his enterprise in the future.

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1.0 INTRODUCTION

We are experiencing today a dramatic change in the methods of producing farm animals and poultry for slaughter and for food products. The production of animals has emerged from the small, individual farm operation into a large-scale industrial enterprise involving hundreds of acres and thousands of animals. Small animals, such as pigs and chickens, are confined within buildings in which the humidity, temperature, sanitation and animal movement are controlled to produce the greatest weight gain in the shortest period of time. Such farms may now be regarded as industries so far as their mode of operation and wastewater problems are concerned. It is only a matter of time until the majority of animals produced for slaughter will be fed in similar environment controlled confinement areas.

Until recently, farms have not been thought of as serious sources of water pollution because of the diverse nature of their activities and the comparatively small scale of each unit. Where pollution matter entered a watercourse - often a ditch - that watercourse frequently was largely self-purified before receiving another discharge. Modern developments in farming are tending to eliminate this safeguard and it is now imperative that these industries should comply with the generally accepted standards applied at present to other agricultural industries such as vegetable canning and sugar beet processing plants.

Confinement housing of animals and poultry is creating an immense waste disposal problem. In the confinement method, feed and water are brought to the animals and no longer do they drop their manure on pastures where it can be absorbed naturally. Instead, the wastes must be collected, stored and then disposed of. Where possible, these wastes are used as fertilizers for field crops and if the farmer grows his own feed, there is generally sufficient land available for this method of disposal.

The livestock or poultry farmer generally, however, is in the animal business, not in crop farming. He relies on commercially available feedstuffs for a considerable portion of his feeding requirements, and thus, he frequently does not have adequate land of his own for the disposal of all the animal wastes. The crop farmer, on the other hand, can usually buy and apply chemical fertilizers more cheaply than he can use free animal manure. The "organic" value of manure is seldom reflected in increased crop yields.

The Ontario Water Resources Commission is the agency responsible for the development, utilization, treatment and management of water resources, including the provision of adequate pollution control measures, throughout the Province. Since farm animal wastes now present a high pollution potential due to the changing nature of farming, the Commission is becoming concerned with the farm animal waste disposal problem.

While the OWRC is concerned with having farm wastes disposed of in such a manner as to minimize the pollution hazard to ground and surface waters, the farmer is generally interested in one of two problems in relation to waste disposal: 1) that of retaining the nutrients of the waste for land fertilization while providing a method of holding the wastes with a minimum of nuisance and expense until it can be applied to the land at specified periods, or 2) disposing of the waste in as economical a method as possible.

Through combined research with the agricultural industry the OWRC is attempting to arrive at a method of waste disposal which will fulfill the interests of both parties concerned.

2.0 REASONS FOR CONCERN

There is a growing public reaction to the deterioration of lakes, rivers and other bodies of water, brought about by their use, and often misuse, for all kinds of purposes, and as a result of natural changes. Attention is being focused on how this situation is being, can be, and should be improved. It is not the problem that is new, just the growing public awareness and concern.

Deterioration of our lakes, rivers and other water bodies is a relative term because water quality is judged according to the use for which that water is required. Conditions which are ideal for a water supply may be far from ideal for a fishing water. A pollutant, then, is anything which contributes to causing the water body to fall short of the quality standard objectives appropriate for the uses intended. Examples of pollutants are dissolved or suspended materials having an oxygen-consuming ability, the presence of new or increasing quantities of chemicals which, by upsetting the equilibrium of the biota, cause undesirable changes, bacteria, viruses and under certain circumstances, heat.

Domestic sewage was the first and perhaps the most obvious pollutant to warrant serious attention. The extent to which treatment facilities are provided and the degree of treatment given to sewage has progressively increased over the years, and will continue to do so. The OWRC is largely responsible for this activity within the Province of Ontario.

Industrial wastes were the next to receive attention. The contents of most wastes remaining from the various manufacturing processes pose as great a problem if not greater, as municipal sewage if they are allowed to reach waterways in an untreated state. To meet this problem the OWRC co-operates with industry in its efforts to find solutions to its waste treatment and disposal difficulties.

Agricultural watersheds have always been a source of pollution to surface waters, but the concentrations of pollutant were minimal due to the diverse nature of farming

and relatively low concentrations of animals per acre of farmland. Although the method of handling manure generally used, that of piling manure in the barnyard, created a potential source of pollution in the form of runoff, the topography of Ontario is such that seldom did this runoff directly enter a stream. Where this occurred, the quantity of runoff was generally small and temporary and seldom overtaxed the self-purification capacity of the stream.

With the high concentration of animals, the farms of the present and future have an immense pollution potential. The area of land now required to support a given number of animals is, in many cases, being reduced because of the use of feeding materials not produced on the farm. Such methods cause an increase in the volume of manure produced per acre, and the method of feeding may itself create new and difficult problems in effluent disposal.

A factor which augments the waste disposal problem brought about by the concentration of farm animals is the changeover from solid to liquid manure handling practices. This change has occurred because of a lack of sufficient bedding materials for the animals and for ease of handling. Liquid manures can be easily washed or pushed out of the confinement areas. Use of water in the handling of manure, however, increases the volumes of waste to be handled and increases its pollution potential as runoff.

Pollution from animal feedlots enters a stream along with the surface runoff and therefore discharges to the receiving watercourse only so long as runoff is taking place from the area. If a feedlot is designed so that no water passes over the lot except rain which falls on it, the runoff ceases soon after the rainfall stops. This results in a "slug" load on the stream, and the nature of the pollution is unique in several aspects when compared with conventional pollution sources that are continually discharging. There may be no warning to downstream water users and game fish are frequently trapped in the polluted waters. Considerable research into stream pollution from feedlot runoff has been conducted by Smith and Miner (1964). Downstream measurements of dissolved oxygen and pollutants confirm the plug flow theory. A well designed feedlot, however, should not contribute any runoff to surface waters.

A more obscure form of pollution than that due to runoff may result from a feedlot operation - that due to infiltration and percolation of the liquid portion of the manure past the soil-moisture zone to ground water.

Miner, et al (1966) conducted an investigation to determine the nature of cattle feedlot runoff and to evaluate various techniques to minimize pollutional effects of feedlot runoff. By comparing the runoff from two experimental feedlots, one entirely surfaced with concrete and the other with concrete only around the feed bunks, they found that runoff from a concrete-surfaced lot was more heavily polluted than that from a nonsurfaced lot under similar conditions. In their work, however, they failed to indicate why this was so. It would seem logical that the reason the nonsurfaced lot runoff was lower in pollution was because of the infiltration of the pollutional material into the soil.

A feedlot, then, depending upon location and soil conditions may have to be surfaced to prevent ground water intrusion of pollutants. If it is surfaced, however, an all-out effort must be made to prevent surface runoff from entering a watercourse.

3.0 POLLUTION POTENTIAL OF FARM ANIMAL WASTES

3.1 Magnitude of the Problem

In the year 1966 there were over 5.4 million head of livestock with a value of over $600 million and a total poultry population of 29.5 million at a value of over $44 million, within the Province of Ontario. The wastes produced by these animals are equivalent in strength to the sewage of some 30 million people. Table 1 lists the livestock and poultry in their various components giving the number and value of each.

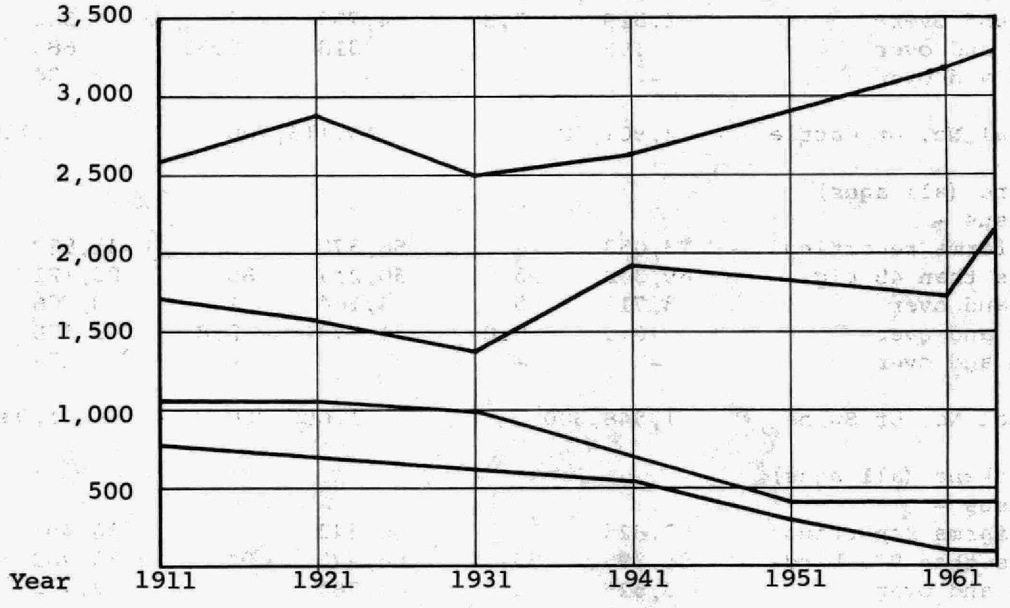
Figure 1 presents a chart showing the numbers of various livestock in Ontario for the years 1911 to 1964. As can be seen, the increase in numbers has not been that great: an increase of 28% in cattle population in the past 15 years and an increase of 12% in swine population within the same period. The percentage increase in poultry has been even smaller. The number of farms producing livestock and poultry, however, has decreased greatly in the past few years, and is continuing to do so at an increasing rate. This means that the concentration of animals is increasing on the remaining farms. It is now not uncommon to have dairy farms of 100 milking cows, beef farms of 500 steers, piggeries of 400 swine and poultry farms of 60,000 chickens. The more concentrated the animals are, the greater the pollution potential becomes.

Table 2 gives some indication of the increase in scale of the farming industry over the past 10 years. Data are presented for cattle, swine and chicken farms. As can be seen, the total number of farms producing cattle has decreased from over 111 thousand to just under 80 thousand. The number of cattle, however, has increased by more than 200 thousand. In 1961 there were no farms reporting over 528 head, however, by 1966 there were 34. The number of chicken farms has decreased by more than one-half in the past 10 years.

FIGURE 1*

Chart Showing Number of Livestock in Ontario (in thousands)

For the Years 1911 to 1964



* Taken from "Agricultural Statistics for Ontario, 1964", Ontario Department of Agriculture, Publication No. 20.

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NOTE: Referring to Figure 1, page 8 of the above publication the lines from top to bottom represent populations of cattle, swine, sheep and horses, respectively.

TABLE 2

Livestock and Chicken Concentrations on Ontario Farms*

	1956		1961		1966	
Cattle (all ages)	No.	% of Total	No.	% of Total	No.	% of Total
Census - farms reporting	111,021		95,041		79,906	
Less than 48 head	97,822	88	75,604	79	56,478	70
48 and over	13,199	12	19,481	21	23,428	30
78 and over	2,529	2.8	4,750	5	7,582	9.5
178 and over	199	0.2	318	0.33	683	0.85
528 and over	-	-	-	-	34	0.04
Total No. of Cattle	2,901,700		3,115,700		3,136,956	
Swine (all ages)						
Census - farms reporting	73,053		56,378		41,827	
Less than 48 pigs	69,342	95	50,214	89	83,121	79
48 and over	3,711	5	6,164	11	8,706	21
123 and over	, 610	0.8	1,573	2.8	3,120	7.5
528 and over	-	-	-	-	174	0.4
Total No. of Swine	1,548,300		1,686,300		1,935,595	
Chickens (all ages)						
Census - farms reporting	87,825		60,342		36,494	
Less than 973 birds	84,295	96	56,578	94	33,762	92
973 and over	3,529	4	3,764	6	2,732	8
2,028 and over	1,169	1.3	1,754	3	1,695	4.6
20,023 and over	-		-		229	0.6
Total No. of Chickens	24,934,000		24,708,000		25,309,000	

* From data kindly submitted by the Ontario Department of Agriculture and Food

3.2 Properties of Animal Wastes

An understanding of the properties of animal wastes is essential in the search for a solution to the problem of their disposal. The properties of manures may be classified as physical, chemical and biological, the relative importance of each depending upon the disposal method being considered.

The physical and chemical properties of animal wastes are affected by the particular characteristics of the animal, the feed ration and the environment. The size of the animal, as measured by its live weight, is perhaps the most important parameter. The sex and breed of the animal affect the manure conversion efficiency under a given environment. The digestibility of the feed ration, the protein and fibre content and the nature of the other feed elements determine the composition of the excreta. The method of feeding greatly determines the amount of wastage.

The quality of the feed influences not only the amount the animal or chicken eats daily, and thus the quantity of manure produced, but also the chemical composition of the waste. Proteins, which contain most of the nitrogen of the feed, vary considerably in digestibility, depending on the source of the protein. The nitrogen of the undigested protein is excreted in the solid feces, whereas the nitrogen of the digested proteins is absorbed and later excreted in the urine, except for a portion which is used to build flesh in the animal. The potassium in the feed is absorbed during digestion, but practically all is excreted. Part of the phosphorus content of the feed is absorbed, but most is excreted in the feces.

Most animal rations include antibiotics for disease control. When large doses of these antibiotics are administered to the animals, a portion passes through the digestive tract, and could severely limit or at times prevent biological treatment of the manure unless it is diluted to levels below the toxic concentrations of these antibiotics.

3.2.1 Physical Properties

The quantity and composition of animal and poultry wastes depend so much on the feed ration and the environment in which the animals are raised that it is impossible to specify exactly what the expected strength and quantity of the waste from a given animal will be. The figures presented in the tables are the average values of a wide range of data given in the literature. They should be used as guidelines only, in the absence of specific data.

Table 3 presents average daily production data taken from current literature for various animals. The values for manure production do not include bedding or litter since their use is minimal in present farming operations where waste disposal is a problem. The values do, however, represent the amount of manure that can be expected to be collected in daily scrapings from pens.

3.2.2 Chemical and Biological Properties

Of the chemical and biological characteristics of manure, the fertilizing constituents have been investigated most extensively. Only recently have data been published on the biochemical and chemical oxygen demand* of the wastes.

Plant nutrients in manures come entirely from the feeds consumed by the animals. The proportions of the nutrients, originally present in the feed, that are expected in the manure, vary considerably since growing animals and milking cows use higher proportions of the feed than do mature animals. On the average about 75% of the nitrogen, 80% of the phosphorus (as P_2O_5), 85% of the potassium (as K_2O) and about 40 to 50 percent of the organic matter of the feed may be recovered in manures. Although the liquid portion of the waste is only 30 to 40 percent, urine constitutes 40 to 70 percent of the fertilizer value of the total excrement.

* Biochemical Oxygen Demand (BOD) is a measure of the quantity of biologically decomposible matter present.
Chemical Oxygen Demand (COD) is a measure of the quantity of chemically oxidizable carbonaceous matter present.

TABLE 3

Average Daily Production of Livestock Manures

	Manure* lb/day	Manure* gal/day
1,000 broilers (0-4 lbs)	250	14.5
100 hens (5 lbs)	45	2.6
10 hogs (30-200 lbs)	70	8.6
2 beef cattle (400-1,100 lbs)	77	9.5
1 dairy cow (1,200 lbs)	72	9.5

* Assuming no dilution

Until the development of the fertilizer industry, animal manures were the main source of plant nutrients. Today, in light of the plentiful supply of commercial fertilizers, the question has been raised if it pays to collect and use animal wastes as fertilizers. An analysis of the manure and a look at the disposal problem, however, indicate that the application of manure to soils is well justified and desired.

Table 4 presents the average nitrogen, phosphate and potassium contents of various animal wastes and Table 5 gives values for the minor fertilizing nutrients.

If sufficient land is available, field spreading of the manure should be encouraged because, if applied correctly, it provides adequate treatment and final disposal of the wastes while adding necessary plant nutrients to the soil.

In land disposal of farm manures, nitrogen is the nutrient which is most likely to cause adverse effects on crops or water supplies when applied to the land in too high concentrations. Thus the rates of manure application to crop lands may be specified in terms of the amount of nitrogen applied. For grasses, an application in excess of 100 to 150 pounds of nitrogen per acre per growth period may cause toxic levels of nitrates in the plant tissue.

Table 6 indicates the land requirements for poultry and livestock manure utilization as determined by the Department of Soil Science, University of Guelph (OAC, 1966).

There is a wide disagreement in data pertaining to the BOD and Population Equivalent of animal wastes. Part of the disagreement can be attributed to the difference in manure production figures reported in the literature. Table 7 shows average population equivalent and BOD figures taken from current literature and indicates the BOD load from typical agricultural enterprises.

TABLE 4

Major Fertilizing Elements of Farm Animal Wastes*

	1,000 Chickens		10 Hogs		1 Cow	
	lb/day	Percent	lb/day	Percent wb**	lb/day	Percent wb
Total Mineral Matter	18	7.20	1.8	2.6	2.1	2.9
Organic Matter	61	24.4	9.4	13.4	8.2	11.5
Nitrogen (N)	4	1.39	0.5	0.75	0.38	0.54
Phosphorus (P_2O_5)	3	0.97	0.3	0.34	0.11	0.15
Potassium (K_2O)	1.5	0.46	0.5	0.52	0.32	0.44

* Values are based on average animal weight
** Percent wet basis, assuming no dilution

TABLE 5

Pounds of Minor Fertilizing Nutrients in
1,000 Gals of Fresh Animal Manures*

Manure	Calcium	Magnesium	Sulphur	Iron	Zinc	Boron	Copper
Chicken	300	24	36	3.9	0.75	0.50	0.12
Swine	47	6.6	12	2.3	0.50	0.35	0.13
Cattle	17	8.7	5.8	0.33	0.12	0.12	0.04

*Assuming no dilution

TABLE 6

Nitrogen Excreted and Estimated Land Requirements for Manure Utilization From Poultry and Livestock

Number of Animals	N-Excreted (pounds)	Required Acreage of Continuous Corn Efficient Use*	Minimum**
1,000 broilers - 10 weeks	155	1.0	0.5
100 laying hens - 365 days	125	1.0	0.5
10 market hogs - 175 days	115	1.0	0.5
2 feeder beef - 365 days	140	1.0	0.5
1 dairy cow - 365 days	140	1.0	0.5

* Acreage required to use efficiently the nitrogen in the manure, that is, maximize the net returns above the cost of the nitrogen applied.

** The minimum acreage that could be treated annually without adversely affecting crop (yield or quality) or ground water.

TABLE 7

(a) Strengths and Loads of Agricultural Wastes

Type of Waste	BOD ppm	Volume gal/unit/day	Load lb BOD/unit/day
Dairy Waste	8,000 - 16,000	8 - 12	1.93
Beef Waste	6,000 - 12,000	4 - 6	0.56
Piggery Waste	1,300 - 13,000	2 - 5	0.25
Poultry Waste	8,500 - 40,000	0.05	0.015 - 0.025
Domestic Sewage	100 - 250	100	0.15

(b) Typical Agricultural Enterprises

Unit	Stock	Daily Load lb BOD	P.E.*
Beef Farm	300 steers	168	1,120
Dairy Farm	50 milking cows	96	640
Piggery Unit	60 breeding sows		
	400 fattening pigs	115	767
Poultry Unit	40,000 laying hens	800	5,333

*Population equivalent based on 100 gal/person/day at 150 ppm BOD

3.2.3 Fertilizer Value

The evaluation of manures as fertilizers may be made by comparing animal manures with commercial fertilizers in terms of nitrogen, phosphate and potassium content. The N, P and K present in various kinds of manure has been presented in Table 4.

Table 4 shows that appreciable amounts of N, P and K are produced annually on farms. Poultry manure has the highest fertilizer value, with swine manure second.

Baines (1964) and Taiganides (1964) have determined the approximate value of animal wastes as to their fertilizing capacity. On the basis of 12, 10 and 5 cents per pound of nitrogen, phosphoric acid and potash, respectively, Taiganides arrived at a potential worth of manures per 1,000 lbs of live animal weight per year of \$71 for hen manure, \$42 for hog manure and \$26 for cow manure. Table 8 presents the fertilizer value, in dollars, of various livestock manures as determined by the University of Guelph (Lane, 1967).

Baines estimated that the value of the 219 million gallons of liquid manure produced annually from cows in Scotland in terms of N, P and K and bought as fertilizers (1957 costs) was £1,267,000 or approximately \$3.8 million. (These values are approximate only but they indicate the value of manure.)

TABLE 8***

Fertilizer Value of Liquid Manure Produced by Different Kinds of Livestock

	Manure* (gal)	Total Value** ($)	Value/1,000 gal ($)
1,000 broilers - 10 weeks	1,000	25.50	25.00
100 hens (5 lb) - 365 days	940	25.25	25.00
10 hogs (30-200 lb) - 175 days	1,510	20.00	13.00
2 beef (400-1,100 lb) - 365 days	3,440	29.25	9.00
1 dairy cow (1,200 lb) - 365 days	3,440	29.25	9.00

* no dilution of the manure
** valuing nitrogen at 10¢ lb, phosphate at 10¢ lb and potash at 5¢ lb
***Taken from "Animal Waste Management and Utilization" T.H. Lane, Department of Soil Science, University of Guelph. Presented at the Ontario Pollution Control Conference, Dec. 4-6, 1967, Toronto.

4.0 HANDLING OF FARM ANIMAL WASTES

The conventional method of handling manure has been to use sufficient bedding to keep the manure relatively dry and then to move it out of the confinement area and deposit it into a manure pile. Piling of manure, however, permits wastage of a large portion of the liquid waste which may contribute considerably to ground and/or surface water pollution through percolation and runoff. With the lack of sufficient bedding material and the increase in animal concentrations, a new manure handling method had to be developed because of this health and pollution hazard. Manure cannot usually be allowed to accumulate in the confinement area until use because of the sanitation hazard of fly breeding, odours, dust, animal health or potential water pollution.

In large production units, manure is handled both mechanically and hydraulically. Mechanical removal of the wastes is normally done with tractors, manure spreaders or with permanently installed equipment, such as shuttle conveyors, floor augers or pumps.

Hydraulic removal of the manure from the building can be accomplished by continuous or periodic flushing of the manure with water. Water flushing greatly aids in odour control within the building but requires considerable amounts of water and adds to the volume of waste produced.

Modern developments in agricultural methods lend themselves to an alternative method of waste collection. The loose housing system - especially with the addition of cubicles - is such a development on the dairy farm. The milking cows are housed in a building with cubicles and a slotted walking area with access to a feeding area. The manure passes through the slots into a tank below. This material is free from bedding, which is retained in the cubicles, and results in a liquid manure, and the system overcomes the problem of the animals being in direct contact with their wastes.

Pigs and beef cattle are now being raised in similar systems with a slotted floor at the back of the pens. Again the manure is forced through the slots to a holding tank below. Water may be used to clean down the floored part of the pens.

The rearing of poultry in cages allows the utilization of a similar system whereby the droppings are collected, usually in stages below tiered cages, scraped mechanically to one end, and may then be scraped into a tank. Generally, there is sufficient spillage from water troughs to maintain a liquid manure.

Where it is impossible or undesirable to renew or adapt buildings to this kind of system the liquid wastes can be collected separately from the solids and again stored in holding tanks until distribution on the land is possible. The solids are dealt with as such, requiring conventional manure spreading equipment.

Generally, the farm animal waste disposal problem is one of collecting and holding manure until it can be distributed on the land, this being generally in the spring and fall depending upon the crops being grown. The difficulties arising in such a waste disposal method involve the size of tank required to store the manure, the odours and gases released, and in some cases, the difficulty of mixing the contents before disposal on the land.

5.0 STORAGE OF FARM ANIMAL WASTES

Wherever possible, farm animal wastes should be disposed of on farmlands, not only because of the fertilizing value of the manures, but also because it affords an inexpensive method of complete disposal of the waste. However, to conserve and to obtain maximum utilization of the plant nutrients, and to avoid possible pollution of surface waters due to runoff, the waste should be incorporated into the soil by ploughing or discing immediately after it is applied. Thus, depending upon the crop rotation and climatic and soil conditions, the application should generally be made in the spring and/or in the fall. To enable this, all waste must be collected and stored until such time as it can be applied. This necessitates having an allowable storage capacity of at least six months accumulation of waste. Manures may be stored either in a solid or a liquid state.

Storage of solid manures is generally accomplished by permitting the waste to accumulate in the buildings or feedlots as it is dropped, or moved out of the confinement area and piled. If it is not removed periodically from the confinement area, bedding or litter must be added to absorb and conserve the liquid portion of the manure. If no bedding or litter is added, swine and poultry manures liquify within a few hours after being excreted. Manures from animals fed high roughage diets, such as cattle and sheep, liquify readily with mixing; for this, trampling of the manure by the animals is all that is required.

Storage of liquid manures has been practiced for some time by use of specially constructed tanks of steel or concrete or by use of lagoon-like ponds. Because of the increasing trend toward liquid manure handling, storage tanks will be used more frequently in the future. In order to be effective, such storage facilities must provide the following functions: capacity to hold the accumulation of manure between periods of land application, agitation to mix the manure to a uniform consistency prior to emptying, pumping equipment to remove the manure from storage to a liquid spreader. Such storage units should be watertight and should not receive dilution from runoff.

Table 9 presents average monthly volumes of various livestock manures. When considering the size of storage tanks a factor of 1.4 (1.5 for poultry) should be used to allow for dilution water from automatic water bowls, etc.

Storage tanks may be installed either inside or outside of the livestock building. Storage tanks inside the building may be less costly to build and permit effective use of slotted floors or walkways but may well be a health hazard to humans and livestock, if improperly designed and operated.

Storage of liquid waste with subsequent disposal to the land is often the simplest and most inexpensive method of disposing of the waste.

Liquid manure storage, however, is not without its problems; namely, in the amount of odour emission of noxious gases and the possible contamination of rivers and streams. Gases in the form of hydrogen sulphide, ammonia and methane - products of anaerobic conditions in manure - have previously presented few problems to farmers, except for the offensive smells associated with them. But now that manure is being collected and held indoors, adequate and continuous ventilation is necessary to dispel pockets of these gases, which, at certain concentrations, can be fatal to both livestock and humans.

Release of noxious gases occurs primarily at the time of emptying the tank. This is because a crust tends to form on the top of the liquid preventing the escape of these gases and upon agitation this protective crust is broken. Thus when agitating manure located inside the livestock building, adequate ventilation is a necessity. All humans should be evacuated, as well as, if possible, the livestock.

Because of the odours and health hazard involved with the storage of farm animal wastes, considerable interest has been given to the aeration of storage tanks to reduce the formation of noxious gases. In maintaining an aerobic state in the tanks, the only gas produced in any quantity is carbon dioxide which, to a large extent, will remain in solution as bicarbonate. Aeration of swine waste is considered by Ingrens

TABLE 9*

The Average Monthly Volume of Undiluted Manure
From Different Kinds of Livestock

Livestock	Monthly Volume of Manure (cu ft per animal)
Boilers (0 to 4 lbs)	0.07
Laying Hens (5 lbs)	0.125
Hogs (30 to 200 lbs)	4.1
Beef Cattle (400 to 1,100 lbs)	22.5
Dairy Cattle (1,200 lbs)	45.0
Sow and Litter	12.0

* Taken from "Liquid Manure - Part 2: Handling for Utilization in Crop Production". Paper prepared by F. R. Hore and J. Pos, School of Agricultural Engineering, University of Guelph.

and Day (1966) and can be accomplished quite simply with air spargers located at the bottom of the tank. Several farmers in Ontario have devised their own aeration equipment using their ventilation systems as the air supply. If air is introduced only to lessen the odour problem and health hazard, relatively small amounts of oxygen are required as compared with that required for aerobic treatment.

6.0 TREATMENT OF FARM ANIMAL WASTES

However desirable the utilization of farm wastes may be, there remains the problem of those enterprises where large quantities of wastes are produced at such a distance from suitable agricultural land as to make disposal in this way impossible, or less economical than treatment followed by disposal of a purified or partially purified effluent.

In manure treatment, the eventual disposal of the waste is an important factor since it defines the requirements as to the degree of treatment. If the effluent is to be discharged directly into a stream, the waste must be treated to meet the objectives set by the OWRC. If the production unit is close to a residential area, the treatment must stabilize the manure so as not to create nuisance conditions. However, if manure is to be disposed of within the property of the producer, than a process that would control the flies, odours and nuisance at a level set by the person or persons concerned would be satisfactory, provided that the treatment did not endanger the health of either the animals or the people involved or contribute to ground and/or surface water pollution.

Basically, treatment and disposal must ensure four things: that there is no hazard to the health of farm animals if disposal is to farmland; that treatment facilities are flexible in design and operation to allow for the various types and quantities of wastes, some being produced continually and others infrequently; that the performance of the treatment plant justifies its capital and operating costs; that ground and surface water pollution are minimal.

Manure can be decomposed either in the presence of, or in the absence of air. When adequate air is combined with the manure, water, carbon dioxide, salts and stable compounds are left and odour levels are minimal. (For complete aerobic decomposition, air is required at an approximate rate of 1.2 lb O_2 per lb of BOD, or 2,500 cu ft of air per lb of BOD at 3% efficiency of oxygen transfer).

When manure is allowed to decompose in the absence of air, anaerobic bacteria take over and acetic and butyric acids, hydrogen sulphide, methane and ammonia are produced. These noxious products are commonly found in manure pits and anaerobic lagoons, although their presence is not usually noticed until the manure is agitated.

Although farm manure processing may be similar to sewage treatment in physical, chemical and biological phenomena, there is a fundamental difference in purpose. Sewage treatment is designed to upgrade the quality of water that is polluted with organic matter. Manure processing is based on the need to stabilize waste organic matter which is diluted with water. If the manure were dry, much of the sanitation problem would be nonexistent. Studies with conventional aerobic biological systems indicate that they are generally unsuitable as a means of stabilizing farm animal wastes, mainly because of the high strengths involved.

Many processes have been proposed and have been or are being employed for the partial or complete treatment of farm animal wastes. All processes used, however, have their limitations and disadvantages; some much more so than others. Some of the more popular treatment methods are discussed in the following section.

6.1 Physical Treatment

Perhaps the two main processes that can be classified as physical are storing and drying. Neither one is a purification method but both are methods of retaining the waste until it can be disposed of on the land. Storage of manure has been discussed previously.

Drying as a method of manure treatment is attractive because it stabilizes the manure to some degree, reduces the weight considerably, and makes the manure unattractive for fly breeding. Drying can be accomplished in a number of ways. In the warm dry areas, droppings can be aired and dried as they accumulate underneath cages or slotted floors. This method, however, does not apply in humid areas or in closed houses with no sunshine and cool temperatures.

Some research has been done on thin spreading of manure to allow drying, (Hart, et al, 1960, Hart, 1964). In warm climates, manure is spread, disced periodically and, when dried, is piled. Such a method could hardly be applied under Ontario's climatic conditions.

Artificial drying, or dehydration, has been investigated and under certain conditions, dehydration, pelleting and bagging of manures could be profitable provided that a market for large quantities could be developed. Ludington (1963) estimated that manure processing by artificial drying, plus pelleting and bagging would cost 1½ cents per pound of dried manure.

6.2 Chemical Treatment

Of the chemical treatment methods available to the sanitary engineer today it would appear that incineration is the only method that could possibly be employed in treating farm animal wastes. All other methods, if suitable for farm wastes, would be prohibitive in cost requiring elaborate equipment and supervision.

Incineration of farm animal wastes is attractive because it is not only a treatment but also a final disposal. It has been found that poultry manure and probably others as well can sustain its own combustion if the moisture content is below 66 percent. Incineration could be an economical method of manure treatment and disposal to some producers, if a mechanical dewatering device was used to remove the free water from the manure. In dealing with this method of disposal, however, the problem of air pollution must receive serious attention.

6.3 Biological Treatment

There are many biological treatment processes which could be applied to farm animal waste disposal, however, as has been mentioned, all have their own limitations.

6.3.1 Composting

Composting is often proposed as a method of stabilizing manure, and is technologically feasible. However, freshly collected manures are usually too wet to compost well, so either they must be partially dried first or a dry filler material added. Additionally, the carbon: nitrogen ratio of fresh manure is only 8:1 to 12:1; this is too low in carbonaceous matter to compost well. (Good composting requires an initial C:N ratio of 20 or 30:1). Thus, when composting of pure manure is attempted there is either excessive loss of nitrogen or incomplete stabilization.

Manure can, of course, be mixed with carbonaceous material, such as straw or municipal refuse, but such a process would have to be carried out on a municipal rather than a private scale. Waste wood products, such as sawdust, could be used but are generally too difficult for the farmer to obtain.

6.3.2 Anaerobic Digestion

Digestion of animal wastes has been rather extensively researched and it has been found that manures can be satisfactorily digested at rates similar to those for conventional municipal digesters (0.1 - 0.2 lb volatile solids loading/cu ft digester capacity per day). The chief end product of anaerobic digestion is methane gas which can be utilized to provide heat to the influent or digester, and possibly for other purposes.

Small-scale digestion plants treating pig and cow wastes have been described in the literature. Such plants are designed for partial digestion with the production of a sludge with a high fertilizing value rather than for complete purification.

Digestion on the farm is a costly process. The expensive and complicated equipment and the skilled labour necessary make it unlikely that digestion will have widespread acceptance by the farmer.

6.3.3 Lagoon Treatment

Today the so-called "manure lagoon" is perhaps the most extensively used method of treating and disposing of liquid-carried manures. These manure stabilization ponds are strictly anaerobic since their biochemical oxygen demand loading is about 20 times that of aerobic lagoons, and perform similar to digesters. Exfiltration and evaporation usually are sufficient to dispose of the excess water, and the sludge layer builds up at a reasonably minimal rate. Ground water pollution is generally not serious but may be a factor in certain locations.

The purpose of anaerobic lagoons is the destruction and stabilization of organic matter and not water purification. Any effluent would require additional treatment before being released to a receiving stream. They can be used as primary sedimentation units to reduce the load on subsequent treatment units or they may function as liquid or solids holding units where surge capacity is needed and are particularly useful for holding animal wastes prior to field spreading.

The greatest drawback to this method of farm waste disposal is the odour involved with the anaerobic lagoon. Odours are such that lagoon installations should not be considered in proximity to private dwellings. Because of advancing urbanization and the changing nature of farming, public demands will continue to curb the use of this method of disposal.

6.3.4 Aerobic Treatment

Conventional biological filtration processes and the activated sludge process are capable of treating farm wastes if high dilution of the waste prior to treatment is practiced. Discharge of farm wastes to a municipal sewage works will afford an economical treatment to the waste but this is seldom feasible because of the location of the farm. Such a consideration may, however, influence the location of future enterprises. The installation of an activated sludge or biological filtration plant on the farm is unrealistic because of the cost of the process and the requirement of trained personnel to keep it operating effectively.

Consideration has been given to the installation of the extended aeration, package plant process for use on the farm. One such plant has been installed on a large dairy farm in Scotland and was effecting a 70 to 75% reduction in BOD under approximately twice the load for which it was designed. The cost of installation and maintenance of these units is sufficiently low that they could be installed on large agricultural enterprises or for groups of farms.

Biological filtration of settled farm wastes may be satisfactory, using recirculation effluent to dilute the incoming liquor (Water Pollution Research 1959, 1961), but installation costs restrict the use of this plant even more than the extended aeration system.

One treatment system which has been proposed is the combined anaerobic - aerobic system (Loehr and Agnew, 1967). The anaerobic lagoon serves to equalize the periodic slug loads the system receives and provides partial degradation, solution and gasification of organic matter. The aerobic lagoon unit provides aerobic stabilization of the soluble and remaining particulate matter in the anaerobic lagoon effluent. A third lagoon, the polishing unit, could be provided to accomplish sedimentation of the biological solids of the aerated lagoon effluent and for further organic removal.

Again, the problem of odour from the anaerobic unit may make this system undesirable to many operators although there are several inherent advantages to the process.

Another aerobic treatment method currently receiving widespread attention for farm animal waste disposal is the oxidation ditch process as developed and used successfully for domestic sewage treatment in Holland. There are two such full scale installations now in operation in Ontario treating pig wastes.

The oxidation ditch process for treatment of domestic sewage from small municipalities was developed by the Institute of Public Health Engineering T.N.O. in the Netherlands. Basically, the process consists of complete mixing and extended aeration and is a modification of the activated sludge process.

During the years 1963-64, the Division of Research, OWRC followed up a preliminary review of pertinent literature and accumulated operating data by an inspection tour of oxidation ditch installations in the State of Oregon and the Provinces of British Columbia and Saskatchewan. As a result of this study (Guillaume, 1964) it was recommended that the oxidation ditch be accepted as a means of secondary treatment of wastewater of small municipalities, suitable for installation in Ontario.

The use of the oxidation ditch for the treatment of farm animal wastes is a new concept and considerable research is required before widespread acceptance of the process for this purpose is realized. This research, however, is presently being conducted by the OWRC in co-operation with the O.D.A. and F. and it is expected that performance and cost estimates will be available in the near future.

The oxidation ditch is constructed of a racecourse-shaped concrete ditch or a rectangular tank with rounded ends and a dividing wall down the middle, leaving space at both ends for liquid to flow around the ditch from one-half of the ditch to the other. A paddle wheel with metal blades is located along one side of the ditch. The churning action of the wheel circulates the slurry and maintains the solids in suspension. The splashing, aerating action allows aerobic bacteria to decompose the waste without the production of the odorous gases peculiar to anaerobic decomposition.

7.0 ECONOMICS OF FARM ANIMAL WASTE TREATMENT

Although agriculture may now be regarded as an industry it differs in many respects from other industrial enterprises, as the basic economic structure of agriculture makes it difficult to pass on immediately any increase in production costs to the consumer. Because of this, agriculture will perhaps be less likely to accept the costs of waste disposal as readily as other industries.

Assuming the farmer is able to dispose of all his waste on his own land, there are several costs involved: (a) removal of manure from production area, (b) conveyance of it to storage, (c) storage, (d) loading and (e) transport to, and distribution on, the disposal area. This must be balanced with the credit from its use (if any).

The concept of obtaining the maximum profit from the use of livestock manures is rapidly giving way, in large livestock operations, to the concept of disposing of the manure at the least cost possible, doing so under limits of allowable pollution and health and nuisance levels as determined by controlling agencies and the farmer himself. Such limits are highly dependent upon the location of the farm. Thus, manure disposal may be the factor limiting the size and/or location of the livestock producing enterprise. Failure to find an acceptable method of disposal at a low enough cost may compel the producer to terminate his operation in a particular location.

A producer, contemplating setting up an enterprise should take into account the problems involved with waste disposal before deciding on the location and scale of his operation. A producer, now in operation, must regulate his expansion program to his method of waste disposal.

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